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and the greater number of suitable comparison stars which could be found for it.

Another advantage of the selenium and photo-electric methods comes from the fact that the light of a body like a comet, nebula, or star cluster may be compared directly with a point source like a star. In addition to photometric studies of diffuse objects, it is not too much to expect that we shall be able to get a very good measure of the general light of the sky, i.e., measures of the total light of the stars both in and out of the Milky Way.

The photometry of lunar and solar eclipses also presents problems which can be attacked with success. The total light of the corona as well as its distribution will be easy to determine. Measures of the zodiacal light can be made, and also any absorption of star light by these particles near the sun may be detected. This last would require very accurate observations, but would be feasible at a mountain station.

The problems here presented are some of those for which we already have the means of attack, and which will lead to definite results. Besides what may be predicted in a way there is always the probability of something unexpected, and it is evident that only a beginning has been made in the use of the new methods.

THE COMPOSITION OF BRACHIOPOD SHELLS

By F. W. Clarke and W. C. Wheeler
UNITED STATES GEOLOGICAL SURVEY, WASHINGTON

Presented to the Academy, April 8, 1915

The present communication[1] is part of a much larger research relative to the inorganic constituents of marine invertebrates. The object of the investigation is to determine, more definitely than has been done hitherto, just what substances are contributed by each group of organisms to the marine sediments, and therefore to the formation of marine limestones, with especial reference to their magnesian and phosphatic varieties. A few analyses of brachipod shells are already on record; and they show that they fall into two chemically distinct groups—one calcareous, the other highly phosphatic. This conclusion is supported and emphasized by the new data obtained by us, which, however, bring out some minor peculiarities that seem not to have been previously observed. For our material we are indebted to the kindness of Dr. W. H. Dall, who selected typical specimens from among the duplicates in the collection of the U. S. National Museum. First in order come five brachiopods representing as many genera in the calcareous group. The species analysed are as follows:

1. *Terebratula cubensis*, Pourtalès. Coast of Florida.
2. *Terebratulina septentrionalis*, Gray. Eastport, Maine.
3. *Laqueus californicus*, Koch. Esteros Bay, California.
4. *Rhynchonella psittacea*, Gmelin. Shetland Islands.
5. *Crania anomala*, Müller. Coast of Norway.

Actual analyses

	1	2	3	4	5
SiO_2	0.06	0.50	0.18	0.14	0.21
$(Al, Fe)_2O_3$	0.04	0.14	0.47	0.23	0.26
MgO	0.44	0.62	0.32	0.23	3.90
CaO	54.96	51.79	54.48	53.76	48.67
SO_3	0.21	0.66	0.21	0.31	0.97
P_2O_5	trace	trace	trace	0.17	0.25
Loss on ignition	44.35	45.28	44.46	44.81	45.38
	100.06	98.99	100.12	99.65	99.64
CO_2 calculated	43.42	40.55	42.91	42.16	40.88
Organic matter*	0.93	4.73	1.55	2.65	3.52

* Approximate. Loss on ignition minus CO_2.

Rejecting organic matter and recalculating to 100%, the analyses assume the following rational form.

Revised analyses

	1	2	3	4	5
SiO_2	0.06	0.52	0.18	0.15	0.22
$(Al, Fe)_2O_3$	0.04	0.15	0.48	0.23	0.27
$MgCO_3$	0.93	1.37	0.68	0.49	8.63
$CaCO_3$	98.61	96.78	98.30	98.20	88.59
$CaSO_4$	0.36	1.18	0.36	0.55	1.72
$Ca_3P_2O_8$	trace	trace	trace	0.38	0.57
	100.00	100.00	100.00	100.00	100.00

For comparison, the analyses of the following calcareous brachiopods, made elsewhere, are significant:

6. *Terebratula* sp. Collected by Pourtalès between Florida and Cuba. S. P. Sharples analyst.[2]

7. *Terebratulina caput serpentis*. Locality not given. F. Kunckell analyst.[3]

8. *Crania anomala*, Müller. Locality not given. Kunckell, analyst.

9. *Waldheimia cranium*, Müller. Locality not given. Kunckell, analyst.

10. *Waldheimia cranium*, Müller. Collected by Norwegian North Sea Expedition, Station 255, latitude 68°.12′ N., longitude 15°.40′ E., in 624 metres depth, and at bottom temperature 6°.5 C.

11. *Waldheimia cranium.* Lofoten Islands. Analyses 10, 11, by L. Schmelck.[4]

Older analyses of calcareous brachiopods

	6	*7*	*8*	*9*	*10*	*11*
SiO_2	....	....	....	....	0.60	?
Fe_2O_3	trace	....	....	....	0.40	0.15
$MgCO_3$	trace	1.05	3.40	....	1.20	1.40
$CaCO_3$	98.39	94.60	87.80	96.20	96.20	95.58
$CaSO_4$	....	2.40	2.15	0.90	0.85	?
$Ca_3P_2O_8$	0.61	....	0.28	0.18	....	....
SrO	....	....	....	....	....	trace
CaO	....	....	....	0.30	....	....
MgO	....	....	1.80	0.60	....	....
P_2O_5	....	....	....	....	trace	0.12
Organic matter	1.00	2.55	4.30	2.00	1.24	1.99
	100.00	100.60	99.73	100.18	100.49	99.64

With these analyses ours agree in a broad, general way, although the older ones vary much as regards completeness. Kunckell's analyses, showing free lime and magnesia are suspicious, but only in this detail; otherwise they have confirmatory value. All the analyses show that this group of brachiopods have shells in which calcium carbonate is the principal constituent, and the proportion of organic matter is low. The only aberrant one is *Crania*, which is noteworthy on account of its high percentage of magnesia; in which respect if recalculated to a common basis, Kunckell's analysis agrees approximately with ours. *Rhynchonella* is also interesting for the reason that an analysis by Hilger of shells purporting to belong to this genus are made to be phosphatic, and practically identical in composition with those of *Lingula.* The authenticity of Hilger's material is questionable; and his analysis will not be reproduced here.

In the group of phosphatic brachiopods four analyses have been made by us. On account of the large amount of organic matter in these shells, which possibly varies with the age or maturity of the animal, we prefer to report our results, as others before us have done, in proximate rather than ultimate form.

1. *Lingula anatina*, Gmelin. Coast of Higo Province, Japan. Organic matter, rejected, 40%.
2. *Lingula anatina*, Iloilo, Philippine Islands. Organic matter, rejected, 39.5%.
3. *Discinisca lamellosa*, Broderip. Coast of Peru. Organic matter, rejected, 25%.
4. *Glottidia* (formerly *Lingula*) *pyramidata*, Stimpson. Coast of North Carolina. Organic matter about 37%. Analysis incomplete for lack of sufficient material.

Phosphatic brachiopods

	1	*2*	*3*	*4*
SiO_2	0.91	0.50	0.85	0.49
$(Al, Fe)_2O_3$	0.54	0.29	0.58	1.16
$MgCO_3$	2.70	0.79	6.68	1.71
$CaCO_3$	1.18	4.25	8.35	?
$CaSO_4$	2.93	4.18	8.37	?
$Ca_3P_2O_8$	91.74	89.99	75.17	74.73
	100.00	100.00	100.00	

These analyses are noteworthy, on account of the unusual proportion of calcium sulphate reported in them. *Discinisca* is especially remarkable in this respect, and also in its percentage of magnesium carbonate. Small amounts of sulphates have often been found in mollusks and corals as well as in the calcareous brachiopods, but in nothing like the proportion given here. A new analysis of *Discinisca*, made upon fresh material, is much to be desired.

In the older analyses of this group the sulphate seems to have been ignored, or at least to have escaped attention. The figures are as follows:

5. *Lingula ovalis*. Hawaiian Islands. T. S. Hunt, analyst.[5]

6, 7. *Lingula ovalis*. Locality not given. A. Hilger, analyst.[6]

8. *Lingula anatina*. S. Cloëz, analyst.[7] Recalculated to 100% after rejecting 42.6% of organic matter.

Older analyses of phosphatic brachiopods

	5	*6*	*7*	*8*
SiO_2	....	0.18	0.17	trace
$MgCO_3$	....	2.94	3.13	....
$CaCO_3$	11.75	10.76	10.86	12.19
$Ca_3P_2O_8$	85.79	84.94	85.24	77.17
$Mg_3P_2O_8$	....	....	....	7.03
$FePO_4$	....	0.77	0.76	3.61
MgO(?)	2.80	....	....	....
	100.34	99.59	100.16	100.00

In this table the relatively high figures for $CaCO_3$ are doubtless due to the neglect of the sulphate determinations. The analysis by Cloëz differs from the others principally in form, that is, in its mode of calculation. If the phosphoric oxide in it is entirely assigned to the lime, then the proportion of calcium phosphate becomes 88.6%, and well in line with the other figures. The amount of calcium carbonate would be correspondingly reduced.

Now to sum up. The brachiopods, as stated at the beginning of this paper, are to be divided into two distinct groups; the shells of one consisting mainly of calcium carbonate with little organic matter; and of the other predominating calcium phosphate with much organic matter. The two groups, although they may be alike structurally, are physiologically quite dissimilar, the chemical reactions involved in building the shells being of two different orders. Such a distinction ought to be significant to biologists, and it is for them to determine what it means. Geologically, however, we can see that the phosphatic brachiopods have probably played some part in the formation of phosphatic sediments, a function which is shared by vertebrate animals and some crustaceans.

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[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Sharples, S. P., *Amer. J. Sci.*, ser. 3, **1**, 168 (1871).

[3] Kunckell, F., *J. prakt. Chem.*, ser. 2, **59**, 102 (1899).

[4] Schmelck, L., *Norske Nordhavs Expedition*, No. 28, p. 129 (1901).

[5] Logan, W. E. and Hunt, T. S., *Amer. J. Sci.*, ser. 2, **17**, 237 (1854).

[6] Hilger, A., *J. prakt. Chem.*, **102**, 418 (1867).

[7] Cloëz, S., *Jahrber. Chem.*, 1859, p. 642. From *l'Institut*, 1859, p. 240.

ON THE OCCURRENCE OF THE LINE 4686 A AND THE RELATED SERIES OF LINES IN THE SPECTRA OF THE PLANETARY NEBULAE

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The line 4686 A and the related series of lines known as the *ζ Puppis* series, or 'sharp series' of hydrogen, were first observed in the spectra of the heavenly bodies. In 1912 Fowler succeeded in exciting them in a laboratory source.[1] More recently they have played an important rôle in certain theories of the constitution of the atom.[2]

The lines in question exist in the spectra of the planetary nebulae, and a number of facts concerning their occurrence have been brought out in the course of an investigation, now being undertaken, of these spectra. This study, while not yet complete, has led to some tentative generalizations on the behavior of certain of the nebular lines, prominent among them the one at 4686, and it may add to the significance of some of the observations of this line if a brief account is given of these. In what follows I shall attempt to state in general terms what appear to me to be the most significant facts gathered from an examination of about a dozen planetary nebulae, and shall make only occasional references to individual objects. A detailed account of all of the observations will appear on the completion of the work. The conclusions arrived at here are, of course, subject to revision in the light of additional data.